IMPROVEMENT OF WHEAT DROUGHT TOLERANCE THROUGH GENETIC ENGINEERING

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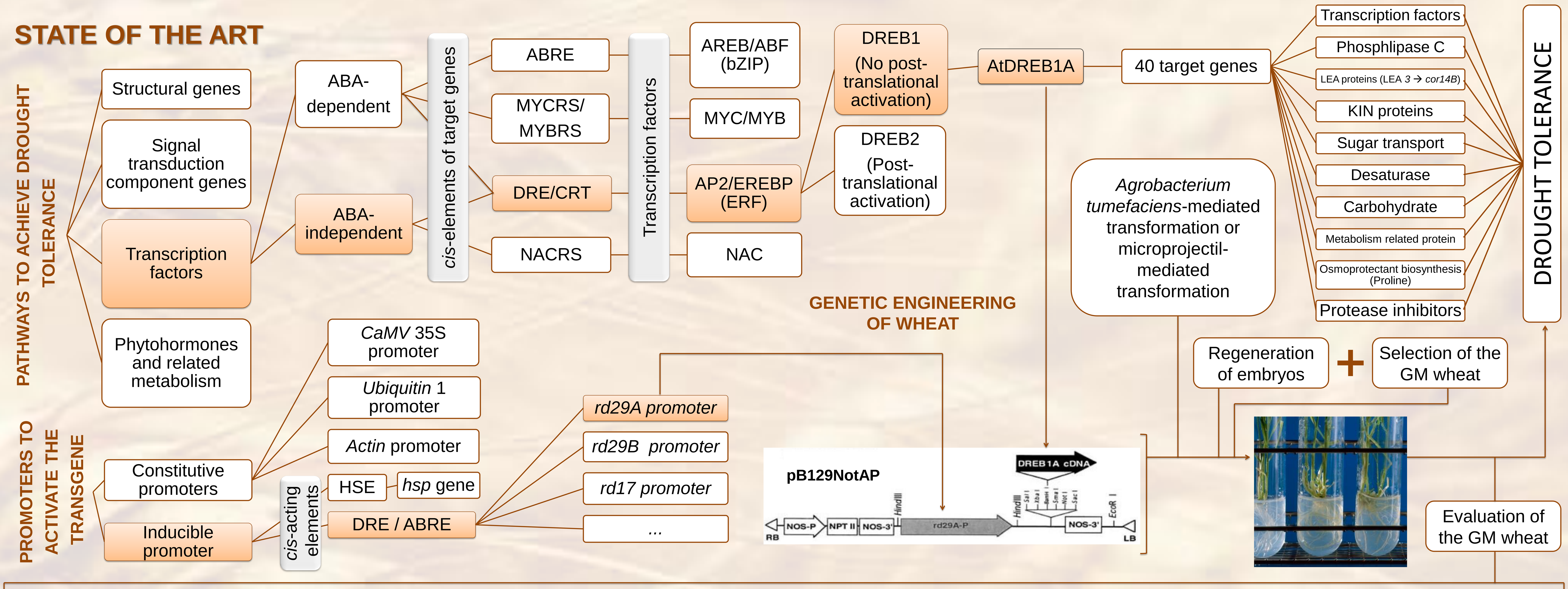
INTRODUCTION

Undoubtedly, drought is one of the main abiotic stresses affecting plants especially cereals such as rice, maize and wheat, these being the major crops worldwide, causing a decrease in crop yields. Besides, wheat *Triticum aestivum* especially, is one of the most cultivated cereals in Catalonia, a place where the aridification of the climate is a reality. Therefore, the development of genetic engineering is being an attractive strategy to overcome this problematic. So far, several research groups have tried to solve this problem in many different ways and in most cases, they have obtained drought-tolerant plants but mostly under greenhouse conditions. However, the problem has not yet been solved in the field. This final project is a review on the research to improve the tolerance of *T. aestivum* towards drought, studying in detail the best way to solve the problematic. Thus, the main goal of these studies is to prolong the survival of wheat under drought and allow its full recovery once ceased, but in any case we do not want to increase production under these conditions.

STATE OF THE ART



RESULTS

TRANGENIC PLANTS UNDER GREENHOUSE CONDITIONS

Fig 1. (A) Phenotype of the *DREB1A* line (left) and control plants (right) after 15 days of water stress and one watering. (B) Root phenotype of GM (left) and control (right).

Table 1. Survival rate (%) and standard error from transgenic plants and control plants (non-transformed Bobwhite) at 23 d after the last irrigation.

Group	Survival rate (%)	SE
WUE-11	48	12
WUE-12	48	12
WUE-13	67	10
WUE-14	45	5
WUE-15	45	9
Bobwhite	19	9
Mean	45	
CV	17	
P>F	0.047	
LSD (5%)	28	

[a] SE, standard error.

Table 2. Water use (WU) (ml), biomass (g plant^{-1}), and water use efficiency (WUE) (mg ml^{-1}plant^{-1}) in transgenic events selected by high water use efficiency (WUE-11 to WUE-15) and high survival after severe water deficit (SL) under greenhouse conditions. Bobwhite and null-event are the control lines.

Strategy for selection	Code	Well irrigated			Water deficit		
		WU (ml)	Biomass (g plants^{-1})	WUE (mg ml^{-1} plant^{-1})	WU (ml)	Biomass (g plants^{-1})	WUE (mg ml^{-1} plant^{-1})
Water use efficiency	WUE-11	1407	3.97	2.93	843	2.56	3.16
	WUE-12	1180	2.90	2.50	710	2.34	3.26
	WUE-13	1336	3.26	2.52	697	1.97	2.78
	WUE-14	1314	3.55	2.77	806	2.64	3.39
	WUE-15	1309	3.37	2.66	777	2.61	3.41
Survival	SL-1	1130	2.64	2.36	853	1.45	1.88
	SL-2	1334	3.21	2.45	902	1.67	1.91
	SL-4	1484	3.08	2.13	977	1.70	1.79
	SL-5	1087	2.43	2.25	783	1.43	1.88
	SL-6	1135	2.67	2.38	783	1.30	1.74
	SL-7	1229	2.76	2.30	868	1.47	1.78
	SL-8	1210	2.82	2.41	818	1.46	1.86
	SL-9	1171	2.71	2.32	770	1.36	1.80
	SL-10	1114	2.46	2.29	880	1.55	1.81
Control lines	Null-event	1252	2.94	2.40	733	1.59	2.37
	Bobwhite	1221	2.74	2.25	729	1.47	2.06
Mean		1243	2.95	2.42	805	1.71	2.22
CV		11.31	16.84	15.21	24.52	33.52	38.19
P>F		<0.001	0.01	0.45	0.07	<0.001	<0.001
LSD (5%)		161	0.57	0.42	173	0.50	0.74

TRANGENIC PLANTS UNDER FIELD CONDITIONS

Table 3. Date, wheat growth stages, and millimetres of water applied by drip irrigation for treatments in the open-field trial, Tlaltizapan, Mexico, 2009–2010. Plants were grown under severe stress (DEF), terminal water deficit starting at anthesis (ANT), terminal water deficit starting in grain filling (GF), and well irrigated conditions (IRR) in an open field trial in Mexico, 2009–2010.

Irrigation date	Growth stage	Severe stress (DEF)	Stress starting at anthesis (ANT)	Terminal stress (GF)	Well-irrigated (IRR)
November 2009	Germination	58	58	58	58
December 2009	Tillering-Booting	10	63	63	63
January 2010	Heading	-	-	40	71
february 2012	Grain fill	(*)[a]	(*)[a]	(*)[a]	34(*)[a]
March 2012	Grain fill	-	-	-	34
Total		68	121	161	260

[a](*) 56 mm from rain on 4 February 2010.

Table 4. Plant performance in a set of 14 transgenic lines selected by water use efficiency (WUE) and survival to severe stress (SL), a null event (Null), and a non-transformed control (BW) grown under severe stress (DEF), terminal water deficit starting at anthesis (ANT), terminal water deficit starting in grain filling (GF) and well-irrigated conditions (IRR) in an open field trial in Mexico, 2009–2010. Variables: BMA, dry above-ground biomass shortly after anthesis (g m^{-2}), canopy temperature (ºC), and YLD, yield (g m^{-2}).

Strategy for selection	Code	BMA (g m^{-2})				YLD (gm^{-2})			
		(DEF)	(ANT)	(GF)	(IRR)	(DEF)	(ANT)	(GF)	(IRR)
Water use efficiency	WUE-11	314	499	464	570	182	241	249	366
	WUE-12	364	486	441	476	215	236	260	333
	WUE-13	321	442	-	557	217	262	254	297
	WUE-14	384	495	461	470	201	265	271	326
	WUE-15	355	521	534	531	201	265	278	337
Survival	SL-1	322	490	565	472	188	264	309	285
	SL-2	255	490	457	465	184	232	239	315
	SL-4	306	410	424	499	145	181	245	337
	SL-5	291	595	602	503	202	315	316	299
	SL-6	316	537	488	592	181	306	292	352
	SL-7	362	468	585	493	224	332	327	323
	SL-8	338	470	532	520	219	276	324	271
	SL-9	273	436	416	479	205	291	268	333
	SL-10	304	355	562	407	175	286	288	341
Null-event	Null	309	442	492	430	197	261	294	310
Bobwhite	BW	346	459	465	538	217	324	321	297
Mean		325	468	487	504	199	199	287	318
CV		17.30	13.53	12.41	15.21	11.79	11.79	9.19	6.41
P>F		0.67	0.16	0.02	0.58	0.13	0.13	0.01	0.007
LSD (5%)		115	129	123	157	47.90	47.90	53.91	41.89

CONCLUSIONS

1. Tolerance to drought can be achieved using a TF gene because it regulates several genes including other TFs.
2. A good choice is to focus on the DRE family because it is the best studied group of TFs in this field and specifically on the AtDREB1A.
3. Moreover, an important step to design a transgene is the promoter; the *rd29A* promoter is an effective water-stress-inducible promoter in wheat.
4. From greenhouse experiments, the transgene increased the survival rate of transgenic plants without growth retardation.
5. The positive association between WUE and BM suggests that an increase in grain yield is possible if there is an increase of WUE in GM plants.
6. Under field conditions, plants selected by WUE were found to combine both an acceptable yield and stable performance across the different environments generated by the treatments.
7. However, no increases in grain yield under stress have been reported. Therefore, it is possible to assume that high yielding-wheat GM lines having the transgene active and integrated in a suitable insertion location would be achievable if adequate transformation and screening protocols are implemented.
8. To conclude, although up to the date no transgenic wheat has yet been commercialized, it has the potential to contribute to a "major leap forward in drought tolerance potential".

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